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Development and Growth of the Hawk Wing Conch, *Strombus Raninus* (Gmelin, 1791) in Culture Conditions: Egg Mass to Early Juvenile Stage

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Abstract. Eight captive-laid egg masses of hawk wing conch, *Strombus raninus*, were used to describe egg mass characteristics, growth rate, and shell morphology of larvae and early juveniles. The egg strand diameter was 357.3 ± 7.8 µm; the egg capsule diameter was 129 ± 7.0 µm; the number of egg capsules per mm was 19 ± 1.4; and the number of eggs per coil of strand was three. Hatching occurred three to four days after the egg mass was laid. The larval shell length at day one was 147.0 ± 24.0 µm. The veliger growth rate was 27.4 µm per day. The mean size at metamorphosis was 1407 ± 86.3 µm, and metamorphic competence occurred at 46 days. Percent metamorphosis using H_2O_2 with a 24 h exposure varied from 16.6% to 52.8%, with a mean of 33.2 ± 18.3%. Post-metamorphic juvenile growth rate was 93.1 µm per day. Shell length was 4769 ± 1235.1 µm 36 days after settlement, and shell color was white with brown bands. This data is useful for larval identification from field samples and to aid in culture methodologies.

Key Words: conch, culture, development, growth, larvae, *Strombus*.

INTRODUCTION

In the Caribbean region, there are six conch species belonging to the family Strombidae: *Strombus gigas* Linnaeus (queen conch), *S. costatus* Gmelin (milk conch), *S. raninus* Gmelin (hawk-wing conch), *S. alatus* Gmelin (Florida fighting conch), *S. pugilis* Linnaeus (West Indian fighting conch), and *S. gallus* Linnaeus (rooster-tail conch) (Abbott, 1974). Queen conch, *S. gigas*, is the most commercially fished gastropod in the Caribbean (Randall, 1964; Appeldoorn, 1994). However, populations have been seriously depleted by overfishing (Stoner, 1997), and the species is now considered commercially threatened (Wells et al., 1983).

Aquaculture has been suggested as a way to replenish natural queen conch populations (Berg, 1976; Brownell, 1977; Ballantine & Appeldoorn, 1983; Davis & Hesse, 1983; Davis, 1994). Methodologies to culture queen conch larvae and juveniles are well established and are used in commercial and research facilities (Creswell, 1984; Corral & Ogawa, 1987; Davis, 1994; Glazer et al., 1997; Davis, 2000; Davis & Shawl, 2005; Davis, 2005). Knowledge of these culturing techniques has allowed researchers to experiment with other *Strombus* species. Research has been conducted to determine growth rates of juvenile *S. costatus* (Berg, 1976; Brownell, 1977; Appeldoorn, 1985), to test phytoplankton diets for *S. gigas*, *S. pugilis*, and *S. costatus* larvae (Aldana-Aranda & Patiño-Suarez, 1998); and to raise juvenile *S. gigas*, *S. costatus*, *S. alatus*, and *S. raninus* in captivity for food production and the aquarium trade (Shawl et al., 2003; Shawl & Davis, 2004).

The larval development of *S. gigas*, *S. costatus* and *S. pugilis* is well known (D'Asaro, 1965; Brownell, 1977; Rodríguez-Gil et al., 1991; Davis, 1994; Brito et al., 2000). However, the information related to *S. raninus* is limited to description of the species, (Clench & Abbott, 1941), distribution (Flores, 1964; Percharde, 1970; Alcolado, 1976; Brownell, 1977), behavior (Berg, 1975), and predation (Arnold & Arnold, 1969; Wodinski, 1969). There are only three studies related to the development or growth of *S. raninus* larvae (Robertson, 1959; Davis et al., 1993; Shawl & Davis, 2004). The main goal of this work was to fully describe the development of the hawk wing conch, *S. raninus*, from egg stage to early juvenile stage in laboratory culture conditions. This information can be used to identify larvae collected in the field, and to aid in the culture of this species.

MATERIALS AND METHODS

The experiment took place from January to March 2002 at Harbor Branch Oceanographic Institution (Harbor Branch), Ft. Pierce, Florida. Egg masses were obtained from captive *S. raninus* adults that were held in the conch facilities at Harbor Branch (Shawl & Davis, 2004). Each egg mass was incubated in an upwelling screen container (15 cm diameter × 15 cm height) with 50 µm screen on the bottom (Davis, 1994). A continuous flow of re-circulating water (100 ml per

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min per egg mass) passed by the egg strands at a temperature of 26 ± 3°C.

To determine the hatch day, a section of the egg mass strand was observed daily using a dissecting microscope (40×). Veligers were ready to hatch when the embryos rotated in the egg capsules. The structures visible prior to hatching were the velar lobes, eye spots, and orange pigments on the foot (propodium). Using a dissecting microscope (40×) equipped with and eyepiece micrometer, eight egg masses were used to measure egg strand diameter (n = 3 measurements per egg mass), number of eggs/mm of egg strand (n = 3 measurements per egg mass), and egg capsule diameter (n = 5 measurements per egg mass). The mean and standard deviation were calculated daily for each set of measurements.

When the egg masses were ready to hatch a portion of each egg mass was placed in the bottom of a 4 L bucket that was filled with 10 µm filtered and UV-treated seawater. Culture water was static and aeration was not necessary. Initial larval density was 100–200 veligers per liter (Davis et al., 1993), and the final density in the buckets was 15 veligers per liter. Culture water was changed daily with the aid of a siphon. The veligers were collected on a 100 or 250 µm sieve depending on the developmental stage (Davis, 1994). Larvae were fed Tahitian *Isochrysis* at an initial density of 4000 cells per mL which was increased to 7000 cells per mL over the culture period. The late stage veligers were supplemented with *Chaetoceros gracilis* at 3000 cells per mL of culture water.

After an egg mass hatched, the larvae were observed daily with a dissecting microscope (40×). Up to seven egg masses were used to follow larval growth and development. Daily shell length (SL) measurements, apex to shiphonal canal, were recorded for ten veligers starting one day after hatch until competence (46 days). The number of velar lobes, number of shell whorls, foot development, shell beak, and foot pigmentation was described. As larvae approached metamorphic competence, features such as the presence of ctenidium, foot pigmentation, and eye migration were recorded. Scanning electronic microscopy (SEM) photos of larval shells were taken at every 15 days of development (1, 15, 30 and 45 days old), using a Scanning Electronic Microscope Topcon, Model SM-510 from El Colegio de la Frontera Sur (ECOSUR)-Tapachula, Mexico.

Metamorphosis was induced using 3% hydrogen peroxide (0.06 ml H_2O_2 per L seawater) (Boettcher et al., 1997; Davis & Shawl, 2005). To determine metamorphic success, three replicates of 20 animals each were placed into individual 4 L buckets. After four hours of exposure to the H_2O_2 inducer, the number of larvae swimming, metamorphosed, or dead was counted. The larvae were then placed back into the buckets with the H_2O_2 inducer, and were counted again 24 h later. Shell length of newly settled juveniles was measured weekly for 36 days and morphological changes were observed daily.

Table 1

Daily egg mass characteristics of *S. raninus* before hatch. The results are expressed as mean ± standard deviation (n = no. egg masses).

Variable	Diameter of egg strand (µm)	No. egg capsules per mm	Egg capsule diameter (µm)
Day 1 (n = 8)	357 ± 7.8	19 ± 1.4	129 ± 7.0
Day 2 (n = 7)	351 ± 6.2	19 ± 1.2	131 ± 7.8
Day 3 (n = 6)	381 ± 12.1	20 ± 1.7	137 ± 8.9
Day 4 (n = 4)	377 ± 7.2	21 ± 1.7	133 ± 1.0

RESULTS

The egg strand dia, egg capsule dia, and the number of egg capsules per mm were measured for eight *S. raninus* egg masses (Table 1, Table 2). The diameter of the egg strand increased by 20 µm from the spawning day (357 ± 7.8 µm) to one day before hatching (377 ± 7.2 µm). The dia of the egg capsule increased from 129 ± 7.0 µm at day one to 133 ± 1.0 µm by day four (Table 1). The mean number of egg capsules per mm was 19 ± 1.4 (n = 8) (Table 1). The number of eggs per coil of strand was three (Table 2). Eggs hatched in four days at a mean incubating temperature of 26.3°C.

At hatch, the larvae were active and showed positive phototaxis. Newly hatched veligers were 147.0 ± 21 µm SL (n = 5 egg masses) (Figure 1), had two rounded velar lobes (125 µm in length), and a shell with one and a quarter whorls (Figure 2A, B). At metamorphic competence, veliger SL was 1407 µm (n = 1 egg mass), they had six elongated lobes (3000 µm), and the shell had five whorls (Figure 2G, H). Description of larval development is described in Table 3. The growth curve showed a sigmoid shape: a fast growth rate was observed at early stage (until day 30) and decreased as the larvae became competent (Figure 1). The overall growth rate was 27.4 µm per day (n = 111 veligers).

On day 1, the SEM showed that the larval shell has one and a quarter whorls and a small beak (Figure 2). It is elliptical and lightly flat, and the siphonal length was 147 ± 21 µm (n = 5 egg masses) (Figure 2A, B, Table 2, 3). By day 15, the shell has three and a half whorls and a shell length of 599 ± 211 µm (n = 2 egg masses). The first whorl at the top is the protoconch, and the second whorl is located at the center in the columnella axis. The third whorl is twice the size of the second whorl and shows the beakline, which is comprised of three bands (Figure 2C, D, Table 3). The shell has four and a half whorls and a shell length

Table 2

Summary of egg mass and veliger characteristics of *S. raninus*. The results are expressed as mean ± standard deviation (n = no. egg masses).

Variable	Robertson, 1959	Davis et al., 1993	Shawl and Davis, 2004	This study
Diameter of egg strand (µm)	—	321 ± 20 (10)	351 ± 24 (40)	357 ± 7.8 (8)
No. egg capsules per mm	20–23 (1)	21–25 (15)	15–34 (40)	19–21 (8)
Egg capsule diameter (µm)	140 ± 4 (30)	—	123 ± 10 (40)	129 ± 7.0 (8)
No. eggs per coil	—	3	—	3
No. eggs/mass	400,000–460,000	206,000–245,000	91,000–250,000	180,000*
New hatched veliger SL (µm)	—	197 ± 8 (20)	205 ± 10.5 (10)	147 ± 21.0 (5)
Size at competence (µm)	—	1450 ± 53 (10)	1438 ± 72.2 (4)	1407 (1)

* Calculated based on 9 m strand length and an average of 20 egg capsules per mm (Shawl & Davis, 2004).

of 1080 µm (n = 1 egg mass) at age 30 d. Several fine transverse lines are apparent. The last whorl shows the beakline, which appears to have markings in the shape of a "C" (Figure 2E, F, Table 3). Near competency (day 45), the shell has five whorls and a shell length of 1407 µm (n = 1 egg mass). Transverse lines are more noticeable on each whorl, and the beakline is apparent (Figure 2G, H, Table 3).

Towards the end of the larval cycle, the veligers showed a swim-crawl behavior and stayed near the bottom of the culture vessel. The foot, adult operculum, and gills were fully developed at competence. Metamorphosis was induced when ctenidium were observed in 90% of the larvae (38–46 days old). During metamorphosis the lobes were absorbed, the larval heart became non-functional, and the proboscis was developed. The percentage of larvae that completed metamorphosis after four hours was 0.6 ± 0.9% (n = 3 replicates of 20 veligers). When the veligers were reinduced for an additional 24 hr, the percentage of metamorphosis increased to 33.2 ± 18.3% (n = 3 replicates of 20 veligers).

During the first days after metamorphosis the shell was amber in color, and some internal structures could be observed through the shell. There were several longitudinal lines on the shell along with transverse lines. By day 10, small squares were visible on the shell, and the thickness of the shell increased and was no longer transparent. The eyes began to migrate up the eyestalks two days after metamorphosis, but the migration to the top of the stalk was not complete until 30 d after metamorphosis, when the length of the eyestalk was 575 µm and the tentacle length was 750 µm. At 36 d after metamorphosis, the shell was white with brown bands and was 4767 ± 1235.1 µm (n = 29 juveniles) in length. The mean growth rate of the metamorphosed juveniles was 93.1 µm per day (n = 90 juveniles) (Figure 3).

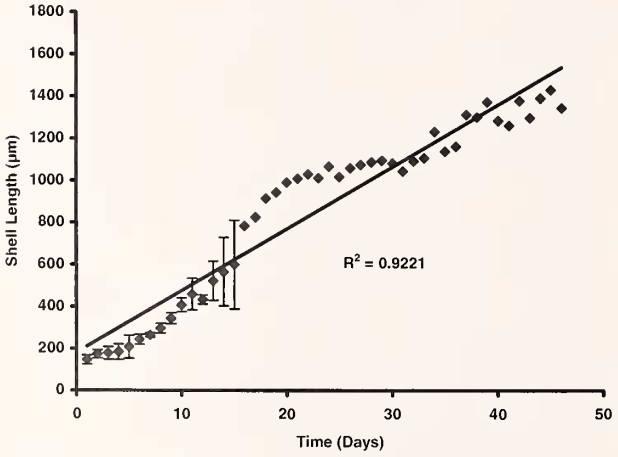

Figure 1. Growth curve of *S. raninus* larvae in laboratory conditions over the experimental period (January–March 2003). Results are expressed as mean ± standard deviation (day 1, n = 5 egg masses; day 2–5, n = 6 egg masses; day 6–8, n = 4 egg masses; day 9–11, n = 3 egg masses; day 12–15, n = 2 egg masses; day 16–46, n = 1 egg mass).

DISCUSSION

Veligers in the family Strombidae have varying larval development. After internal fertilization, the female deposits a gelatinous sand covered egg mass on the substrate. Within the egg mass capsules, the embryos develop to trochophore stage. When development is complete, larvae hatch as veligers and become members of the plankton (Young, 2001).

The egg strand diameter is variable between *Strombus* species. Measurements from egg masses collected in captivity show that the larger species, *S. gigas* & *S. costatus*, have the widest strand diameter, 798 ± 18 µm and 825 ± 56 µm, respectively (Shawl & Davis, 2004). *S. alatus* has a strand diameter of 509 ± 41 µm and *S. raninus* has the smallest diameter, 351 ± 24 µm (Shawl & Davis, 2004). Robertson (1959) observed similar measurements for egg masses collected from the wild in the Bahamas. In this study the egg strand diameter for *S. raninus* (357 ± 7.8 µm) was slightly wider than reported by Shawl & Davis (2004).

The egg capsule diameter measured in this work (129

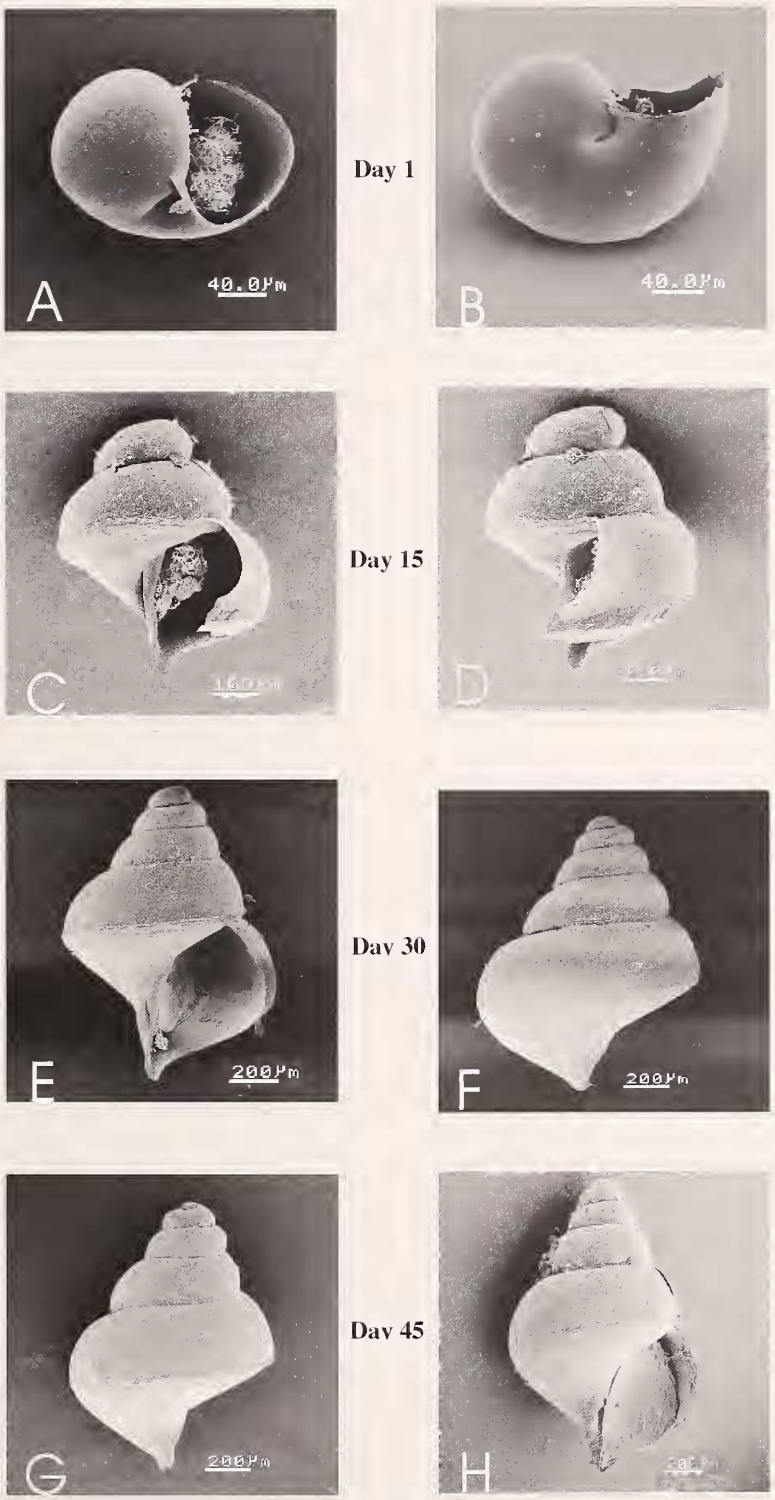

Figure 2. SEM photographs of *S. raninus* larvae. Scale bar in µm.

Table 3

Description of *S. raninus* veliger development.

Days	Development description
1	Larvae are extremely active and show a positive phototaxis. The shell is transparent with 1¼ whorls, a small beak, and it is elliptical and slightly flat. Two round lobes are visible (125 µm), and larvae select food particles. Retinal cells are on the cerebral area (Fig. 2A, B).
2–4	The shell has 1½ whorls. The shell beak has elongated. Larval and adult hearts are visible. Lobes are expanded (150 µm diameter). Food is obvious in the digestive glands, and the crystalline style rotates in the stomach.
5–6	Veligers have two lobes. In the middle of the each velar lobe there is an indentation to form four lobes (200 µm dia). Shell has two whorls and the beak is elongated. Orange pigment is observed on the foot.
7–8	The shell has 2½ whorls and shows an elongated beak. Veligers have two large lobes (350 µm dia) with a larger indentation. The right tentacle is formed.
9–10	Shell has three whorls, and beak is well developed. Lobes continue their indentation to four lobes.
11–12	The shell has 3½ whorls. The veliger has four lobes (500 µm dia).
13–14	The shell has 3½ whorls with an elongated beak (Fig. 2C, D). The first whorl at the top is the protobranch, and the second whorl is located at the center in the columnella axis. The third whorl is twice the size of the second whorl and shows the beakline, which is comprised of three bands. Dorsal lobes begin to divide into six lobes.
15–17	Six lobes are complete. The propodium is more developed and active. There are orange pigments on the propodium, metapodium, and mantle.
18–22	The shell has four whorls and six elongated lobes (600 µm dia). Left tentacle is half the size of right tentacle.
22–25	The six lobes have increased in length (800 µm dia).
25–27	Stomach and digestive gland well developed. Crystalline style rotates actively. Tentacles are still unequal in length. Osphradium is visible.
28–30	Six lobes are well developed (1400 µm dia). The shell has 4¼ whorls (Fig. 2E, F). Several fine transversal lines are apparent. The last whorl shows the beakline, which appears to have markings in the shape of a "C". Ctenidium starts to develop. Eyes are at the base of the stalks. Statocyst visible as two bright dots.
31–33	Shell has 4½ whorls. The propodium is active.
34–37	Metapodium is constricted and thinner.
38–41	Ctenidium is present, foot is active and veliger shows swim-crawl behavior.
42–45	The shell has five whorls (Fig. 2G, H). Transverse lines are more noticeable on each whorl, and the beakline is apparent. Ctenidium is fully developed and present in 100% of larvae. Six long lobes (3000 µm dia). Operculum has a claw.

± 7.0 µm), was larger than that observed by Shawl & Davis (2004) (123 ± 10 µm), but it was smaller than that reported by Robertson (1959) (140 ± 4 µm). The number of eggs per mass for *S. raninus* reported by Robertson (1959) ranged from 400,000 to 460,000. Davis et al. (1993) found that the number of eggs per mass ranged from 206,000 to 245,000, and Shawl & Davis (2004) recorded the number of eggs per mass varied from 91,000 to 250,000. In this work the number of eggs per mass was estimated to be 180,000 based on an average egg strand length of 9 m (Shawl & Davis, 2004) and 20 egg capsules per mm (this study).

The veligers from the egg masses in this study hatched in 80 hr, which coincided with the time observed by Robertson (1959). The morphological features and development of *S. raninus* are similar to other *Strombus* species, such as *S. gigas*, *S. costatus* and *S. pugilis* (D'Asaro, 1965; Davis, 1994; Brito et al., 1999). However, growth rate was slower and time to metamorphosis was longer compared to some other *Strombus* species. In this study a larval growth rate of 27.4 µm per day was calculated for *S. raninus*, which is lower than *S. gigas*, (39 µm per day), *S. costatus* (31 µm per day) (Davis et al., 1993), and similar to *S. pugilis* (25 to 27 µm per day) (Brito et al., 2000). Compared to other *Strombus* species, the hawk wing conch had the longest development time to metamorphosis (46 days). These are similar results from Davis et al. (1993) and Shawl & Davis (2004); they found time to metamorphosis for *S. raninus* to be 40 days and 48 days, respectively. Average development time is 28 days for *S. costatus*, 21 days for *S. gigas*, 31 for *S. pugilis*, and 24 days for *S. alatus* (Davis et al., 1993; Brito et al., 2000; Shawl & Davis, 2004). *S. raninus* have a slightly larger shell length at metamorphosis (1407 ± 86 µm) compared to *S. costatus* (1306 ± 23.9 µm), *S. gigas* (1282 ± 63 µm), *S. pugilis* (1022 µm), and a smaller shell length than *S. alatus*

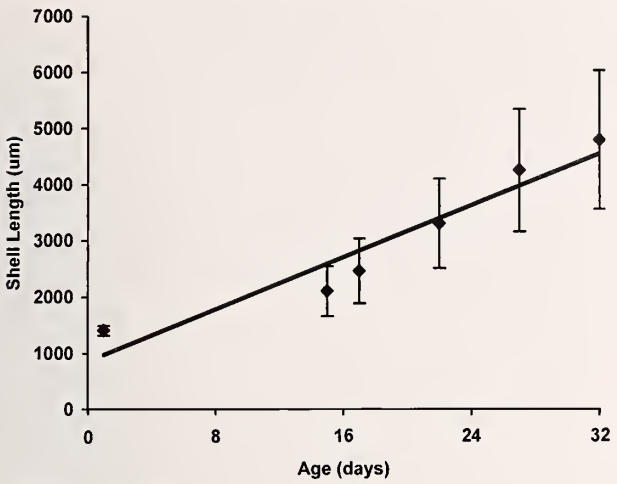

Figure 3. Growth of juvenile *S. raninus* for 36 days following metamorphosis. Results are expressed as mean ± standard deviation (day 1, n = 61 juveniles; day 15, n = 5 juveniles; day 17, n = 35 juveniles; day 22, n = 34 juveniles; day 27, n = 30 juveniles, days 32 and 36, n = 29 juveniles).

(1539 ± 186 µm) (Davis et al., 1993; Brito et al., 2000; Shawl & Davis, 2004).

Shawl & Davis (2004) demonstrated that *S. raninus* could be induced to undergo metamorphosis with low concentrations of hydrogen peroxide; however, percent metamorphosis was low (5.3 ± 2.3%) after four hours of exposure. In this study, 0.6% ± 0.97 of the veligers completed metamorphosis with the same exposure time (4 h). However, there was a substantial increase in metamorphosis when the larvae were exposed to the inducer at the same concentration for 24 hr (33.2 ± 18.28%). Juvenile growth rate (post-metamorphosis) of *S. raninus* had not been previously recorded, and the rate of 93.1 µm per day is slightly lower than the average *S. gigas* growth rate range of 180–250 µm per day.

The hawk wing conch differ from the other *Strombus* species in the larval phase, shell size at metamorphosis, and growth rate. *S. raninus* adults have shown a higher fecundity (Shawl & Davis, 2004) in captivity, compared to other *Strombus* species (*S. alatus*, *S. costatus*, and *S. gigas*). However, their small size at hatch, the long development time, and the low metamorphic success rate does not make *S. raninus* a prime candidate for aquaculture. In natural populations, the extended larval cycle may represent a long residence in the plankton and it could permit a wider dispersion of *S. raninus* larvae in the Caribbean (Davis et al., 1993). This could be due to an inter-specific difference in colonizing new environments, and to diminish competition between *Strombus* species.

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